Document No. FCF-PO-RPT-0001
Revision Final

Fluids and Combustion Facility Document

FCF Preliminary Design Review Panel Report

Date: March 17, 2001

Approved by Thomas L. Labus, Deputy Director, National Center for Microgravity Research

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NASA - Glenn Research Center
Cleveland, OH 44135

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(Official signatures on file with the FCF Project Control Specialist)

Prepared and Approved By:

Thomas L. Labus
Deputy Director
National Center for Microgravity Research
Glenn Research Center

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1.0 INTRODUCTION

The International Space Station (ISS) Fluids and Combustion Facility (FCF) is a research facility being developed for permanent installation in the ISS United States Laboratory Module to support sustained, systematic microgravity fluid physics and combustion science experimentation on-board ISS. The facility must meet the envelope of science requirements in the FCF Science Requirements Envelope Document (SRED), be designed for compatibility with various carrier requirements and constraints, and support fluids/combustion research utilization needs within available ISS resources for ten or more years of operations on-board the Space Station.

The FCF is a unique and highly-capable ISS research facility whose completion and on-orbit operation is wanted and needed by the Microgravity Fluid Physics and Combustion Science Programs. This was evident at the FCF PDR based on strong endorsements from fluids/combustion scientists at the review, Discipline Working Group endorsements of the FCF that the Panel understands to be positive, and the very high level of commitment indicated by Glenn Research Center's (GRC's) Microgravity Science Division to ensure that the FCF is successfully developed and deployed to ISS to provide needed capabilities for the scientific community.

The uniqueness of FCF is clear based on its design and capabilities. The strong desire of other nations to conduct experiments in it and the capability of the facility to support experiments from microgravity research disciplines beyond fluids and combustion was noted by the Review Panel, who observed that technical interchange meetings between FCF and potential international users of FCF were on-going in splinter meetings during the FCF PDR. International/commercial utilization of the FCF is also addressed in the SRED and in the FCF Project Plan. GRC and FCF project should be commended for fostering the development and technical definition of proposed cooperative efforts with ISS International Partners in regards to FCF utilization and for the agreements that are already in place that will ultimately result in commercial utilization of the facility. The Review Panel believes that the potential exists for even greater cross-discipline utilization of FCF than currently envisioned for fluids/combustion, given the modularity, flexibility and capabilities offered by the facility.

The FCF is being developed under a prime, fixed price incentive firm, completion-type contract whose scope includes the production, deployment and initial operation of FCF in ISS. The Panel's review at the FCF PDR was principally a review of FCF prime development activities for the FCF, Combustion Integrated Rack (CIR), Fluids Integrated Rack (FIR), Shared Accommodations Rack (SAR) and associated ground systems, but the Panel also reviewed government furnished equipment items and project implementation plans for the FCF.

The FCF PDR Panel Review was the culmination of a comprehensive FCF PDR review process that included in-depth reviews of FCF PDR documentation and subsystems spanning a period of months preceding the panel review. This review process was very comprehensive and included FCF PDR documentation, subsystem and in-depth design evaluation by ten review teams consisting of technical experts and representatives from GRC, GSFC, MSFC, KSC, JSC, Boeing, the Space Station Payloads Office and the Microgravity Research Program Office. Review Item Discrepancies (RIDs) identified during these in-depth reviews were summarized for the FCF PDR Review Panel and assessments of the FCF were provided by FCF facility scientists in an Executive Session at the FCF PDR. The FCF PDR Review Panel was not asked to disposition or provide board review of the RIDs generated during this review process since cost/schedule implications of the RIDs must be assessed by GRC and the FCF Project Office in relation to the FCF prime, fixed price contract.

1.1 FCF PDR Review Panel Membership

The FCF PDR Review Panel consisted of individuals who are non-advocates and independent of the FCF Project. The Panel members were as follow:

Chairperson:	Thomas Labus	NCMR
Members:	Kenneth Adams	NASA GRC
	James Driscoll	U. of Michigan
	Carlos Fernandez-Pello	U. of California at Berkeley
	Daniel Gauntner	NASA GRC
	Glynn Holt	Boston University
	Robert Jenkens	NASA GSFC
	Michael Miller	NASA JSC
	Irene Taylor	NASA MSFC
	Heide Stefanysun-Piper	NASA JSC

The Panel designation memorandum from the convening authority for the FCF PDR is provided in Appendix A.

1.2 Scope

A five-day preliminary design review (PDR) of the FCF by an independent, non-advocate Review Panel was held in Cleveland, Ohio on February 12-16, 2001. The scope of the review included a Preliminary Design Review for the FCF System (i.e., flight and ground segments), a Delta-PDR for the FCF Combustion Integrated Rack (CIR), a Preliminary Design Review for the FCF Fluids Integrated Rack (FIR), a Conceptual Design Review (CoDR) for the FCF Shared Accommodations Rack (SAR), an assessment of the Fluids and Combustion Experiment Science Requirements Compliance and a review of the FCF Project Plan. Review of FCF subrack payload designs (i.e., Multi-User Droplet Combustion Apparatus, Light Microscopy Module and their associated experiments), steady-state operational phase activities for FCF (i.e., operations, logistics and research utilization after FCF initial operational capability on-board ISS is established) and FCF flight/ground safety were not within the scope of the FCF PDR Panel review, since these were the subject of separate reviews.

1.3 Reference Documents

Document Number	Document Title
GRC-W6000.002	Project Implementation Reviews

1.4 FCF PDR Success Criteria

The NASA Project Management Team provided the FCF PDR Panel with a set of FCF PDR success criteria prior to the PDR. The set of criteria is listed below.

- Compliance of the system FCF design (flight and ground) with the science requirements envelope (i.e. SRED), FCF Systems Requirements and ISS requirements is documented or demonstrated
- Functional and performance requirements of the FCF system are documented and shown to be appropriate at a PDR level
- Proper level of testing directed at resolving feasibility issues is presented and resolved
- Design complies with appropriate design guides and standards, including safety and quality

- Existence and compatibility of the physical and functional interfaces, including software, are established
- Special test equipment and ground support requirements have been determined
- Evaluate the progress and technical adequacy of the project
- Operation of the proposed design has been established
- Past review action items have been properly dispositioned
- Appropriate management plans (development approach, costs, schedule, risks) are defined for development of the FCF

1.5 FCF PDR Review Panel Charter

The FCF PDR Review Panel was chartered to evaluate the FCF design, identify the strengths of the FCF design/project, identify any concerns/weaknesses that exist and recommend any actions to be taken to enhance the probability of success of the FCF Project. Specifically, the FCF Review Panel was chartered to evaluate the following:

1. Assess the overall status of the project in relation to success criteria. Identify the strengths of the FCF Project and FCF Preliminary Design, as well as any concerns that exist.

2. Determine if the preliminary design will meet performance, cost, and schedule requirements.

3. Determine if an appropriate overall system architecture has been established and all external interfaces have been identified.

4. Verify that all feasibility issues have been addressed and project risks have been identified, are acceptable risks and are being properly managed.

5. Recommend whether the FCF Project is ready to proceed with the detailed design phase and whether the FCF Project Plan is sufficiently mature to baseline with a request for FCF system flight implementation authority to proceed.

6. Recommend any actions (Requests for Action) to be taken to enhance the success of the project and submit those RFAs with the formal Panel Report within 30 days of the PDR presentations.

The FCF PDR Review Panel’s responsibility is to provide a written report on the findings of the PDR to the FCF Project Office within 4 weeks of the review (March 16, 2001). This report addresses the strengths of the design, any weaknesses/and requests for action (RFAs) written by the panel to the FCF project based on the review. The RFAs submitted by this panel represent a consensus of the panel members. The reports also include a set of review findings based on the panel charter and final recommendations.

2.0 SUMMARY FINDINGS

In this portion of the report the strengths and weaknesses are addressed. For issues requiring formal tracking and closure, RFAs have been developed by the panel and are located in Appendix D.

2.1 Strengths

The combustion integrated rack appears to be well beyond PDR. The design, including the large combustion chamber and excellent diagnostics, is very mature and will allow conduct of excellent science. The Shared Accommodations Rack (SAR) has plenty of volume. The SAR design appears to exceed the science requirements for that rack. The Fluids Integrated Rack (FIR) has good access for crew members. The open layout will be of high benefit to the crew for access. The diagnostics in the FIR are similar to those utilized by the scientists in their ground-based laboratories. Another major feature of all three designs is the ability to utilize commercial off-the-shelf hardware. This will provide cost savings to the entire program. The SAR is a critical feature of the overall design. The ability to handle the large amounts of scientific data is enabled by the SAR design. The extra space available for experimentation will be of value to the future plans for the entire physical and biological science program.

Significant strengths were recognized for the overall mechanical and thermal design. The use of common hardware and the automation of the design is thought to be very positive. The design is user friendly and will meet the approval of the ISS crew members/payload specialists. There were a number of strengths noted by the panel and they generally fell into the categories of Mechanical/Thermal Design Excellence, user friendly features such as modularity, commonality, and automation, as well as the use of state-of-the art engineering computational tools.

It is evident to the Review Panel that there are a significant number of challenging requirements and constraints that the FCF and its payloads must respond to in order to meet Program needs, be compatible with ISS requirements and be developed and operate within available ISS resources. GRC has implemented a three-tier approach to meet these requirements and constraints that involves; 1) the development, deployment, and permanent installation of FCF systems in ISS which are commonly needed by nearly all fluids and combustion experiments; 2) the use of multi-use experiment inserts that customize FCF for research in specific sub-disciplines (i.e., with plans for significant hardware/software reuse from experiment to experiment); and 3) the ability to tailor/install PI-unique experiment equipment in FCF and its subrack, multi-use experiment inserts to meet specific investigator needs. This approach appears to be very efficient and cost-effective both to minimize the development of needed hardware and to minimize long-term operational phase costs.

The Panel found significant strength in the extent to which FCF has implemented innovative design approaches and solutions to meet challenging performance requirements. The FCF uses fold-out optics benches that improve crew access to equipment, resulting in a very modular, flexible design configuration. The majority of FCF components can be changed out relatively easily on-orbit. This contrast with previous fluids/combustion microgravity experiments and facility hardware that have required much more intensive on-orbit crew effort for hardware change-out, reconfiguration and/or replacement. The FCF design also appears to permit very rapid reconfiguration and equipment replacement by the crew based on the design of standard mechanical, thermal and electrical interfaces used on the optics benches. Technology advancements are incorporated in FCF to increase performance and capability (e.g., use of embedded web software new technology developed by GRC for crew and PI interfaces with FCF and use of next generation switch-gear technology in power control units in FCF).

Owing to the system design approach that FCF has pursued, both automated and crew-tended operation of the facility should be possible. Further, FCF racks may operate independently (as needed for incremental deployment of facility racks) or together for full capability to support research needs and maximize experiment throughput. This is thought to be a very positive approach. The Panel believes that automated FCF operations will be a key to performing more research in the ISS era (i.e., given realities of limited crew availability on-board ISS for research operations) and encourages the FCF team continue to emphasize design features for automated on-orbit operation of racks, avionics, and software as the FCF proceeds through its final design phases and as operational concepts for FCF are firmed up following the FCF PDR.

The Panel noted a significant strength in the high degree of commonality in the design of the FCF system and its subsystems. Identical rack structures/doors, power controllers, computer technologies, control avionics, image acquisition and storage units, diagnostics elements/modules, thermal control system components, software and interfaces have been emphasized in the design of the FCF. This should dramatically reduce the cost of the FCF build, increase options for sharing of FCF capabilities by research disciplines and significantly reduce operational effort, cost and ISS resource needs after FCF is deployed and operating on-board ISS. The Review Panel further noted that FCF has entered into collaborative efforts with other ISS facilities and projects to share the costs of development and/or testing (e.g., same water flow control assemblies used in FCF and the ISS Materials Science Research Facility; collaboration of FCF with the Low Temperature Microgravity Physics Facility for radiation effects testing on radiation-sensitive electronic, etc.). The Panel thought this to be very positive and commends the FCF Project for its efforts in such endeavors that reduce hardware/software costs in the Program.

The Panel found significant strengths in the integrated FCF system and its elements (i.e., CIR, FIR, and SAR racks, flight and ground systems, operations, integration and utilization efforts) as they are being applied to support combustion science and fluid physics research utilization planned by the Microgravity Fluid Physics and Combustion Science Programs for ISS. The CIR provides a unique facility capability on-board ISS for microgravity combustion science experimentation and is the only rack-level capability for combustion research being developed for ISS. The CIR is also the path-breaking rack in FCF's development, since it is the first FCF rack deployed to ISS. Much of FCF's non-recurring development effort and common hardware originate from the CIR and FIR builds. For these reasons, the Panel believes that it is desirable that the development of the CIR proceed swiftly and unencumbered through completion of detailed design and through engineering model testing, based on what appears to the Panel to be a sound design and that the Critical Design Review milestone be achieved as soon as practical. A significant effort lies ahead of CIR during upcoming engineering model production, assembly and testing, which the Panel believes must be a priority of the FCF project in the near future. Before CIR designs are finalized at the CDR, the CIR rack specification must be finalized and engineering model testing must be conducted which addresses both the ability to meet the engineering requirements for the rack and science verification of hardware and interfaces.

The FIR configuration provides a large volume for science experiments on the optics bench. The FIR design also permits very flexible placement and orientation of experiment components on the optics bench and, consequently, will accommodate a broad range of experiments (i.e., fluid physics or other microgravity science discipline experiments). The configuration of the rack provides a "laboratory-type" optics bench environment for configuring and performing research, which seems desired by the fluids science community. It was evident to the Review Panel that extensive effort was applied to the preliminary design of the thermal control system in the FIR to provide temperature levels in the desired range on the front of the optics bench, as needed by fluids experiments. However, thermal stability to maintain optical alignments and the potential need for active control to provide constant temperature environment for fluids experiments should be addressed by the project in the detailed design phase. Based on the preliminary design presented, the FIR is ready to proceed past PDR into detailed design and the engineering model phase, after addressing design issues noted in the text or RFAs of this report.

The SAR permits the FCF to operate at its full performance, providing advanced data handling (i.e., addition of mass storage and additional image processing and storage units), additional FCF science accommodation and the potential for FCF capability upgrades that would support both fluids and combustion science investigations. The flexibility of the SAR configuration to support middeck-type payloads, additional fluids science payloads or unique experiment configurations on the optics bench are also significant strengths of the design. SAR's development is mostly recurring because the majority of hardware used in the SAR is identical to FIR or CIR hardware. Therefore, the cost of the SAR build should be quite low.

Selected FCF-provided diagnostics for fluids and combustion are outstanding in their commonly needed features/capabilities to support fluids/combustion experimentation and in their modular design. The Panel noted that the capability of image acquisition systems and diagnostics planned for FCF and the initial FCF payloads (i.e., MDCA and LMM) are very extensive and appear to represent unique capability that will exist on-board ISS. The suite of diagnostics planned to be provided by FCF seems appropriate to the Panel, though an FCF Project assessment of the types and/or quantities of diagnostics support equipment planned for fluids (e.g., lenses, mirrors, light sources, etc.), based on projected utilization, seems timely based on comments and inputs received from scientists at the PDR.

The FCF Project is being very proactive in addressing operating environment issues such as design for reducing acoustic noise and microgravity disturbances in the FCF design. The Project has recognized these as significant risk areas and is working toward designs to meet challenging requirements in these areas. FCF has also prepared control plans to address these areas. GRC recently installed test laboratories for acoustic noise and microgravity emission evaluations, which will be used to support FCF hardware developments and testing. However, in the Microgravity control area the Panel believes that there is significant effort beyond prudent design practice and testing associated with meeting microgravity acceleration requirements for a facility such as FCF where the configuration of the facility will change with the addition of new and unique payload equipment during its operational life. Models that predict the microgravity environment must be developed and test-correlated with the FCF flight units prior to deployment of the flight hardware to ISS. The Review Panel encourages the FCF Project to address the need for computational tools and analytical requirements, in addition to design and testing, to fully address the acoustic and microgravity disturbance areas.

2.2 Weaknesses

Areas of concern and weaknesses noted by the FCF PDR Review Panel are indicated in this section and within the RFAs.

A chief concern of the Review Panel was to what extent the system is designed to meet the requirements (science, programmatic, and technical). There is a general concern of whether the design can accommodate the 5 base fluid, 5 base combustion experiments per year. A comprehensive traffic flow analysis needs to be conducted and an integrated operations timeline needs to be developed. Close attention should be especially given to ISS resource constraints (i.e., data management, power, etc.). It may be that the original set of science requirements were unreasonable or ambiguous. NASA needs to closely look at the demand on data handling and the need to determine a split on housekeeping and science power requirements. The entire science requirements picture needs to be reassessed given current reality. The Panel strongly advises development of a stronger communication path between the hardware developer and the scientific community to ensure that important science requirements and/or design features are not compromised to the extent that the long-term capability of the FCF could be impacted.

Concern was raised that the operations concept for the integrated facility was not discussed. The Panel thinks that it is very important that the operation and logistics for the FCF systems be incorporated during the design phase. Other systems level issue of concern includes the apparent lack of progress on system software and avionics. In addition, the design needs to implement a system level plan to control mass growth to ensure that the system design will meet requirements. The hardware developer needs to provide systems level metrics to enable all parties the visibility necessary to measure project progress including Risk/Issue/TBD closures. The contractor needs to focus their future efforts more intensely on operation of the entire FCF system including the racks and ground system.

A number of RFAs address open design issues. The developer is strongly encouraged to officially process the CIR/FIR/SAR requirements needing exception. These are open issues representing project risk. There also still remain a number of packaging concerns that were not adequately addressed at the review. The issue of ARIS needs to be resolved by the NASA Program Management. The issue includes design compatibility and scheduled delivery. This is a major project risk. The current design is based upon certain ARIS assumptions which need to be clarified to allow the design to proceed. This needs to be completed very soon. In addition, the unresolved review item discrepancies related to government furnished equipment is an issue. This equipment was out of scope for the PDR but clearly needs to be addressed. No complete set of delivery schedules and hardware or software fidelity was presented. This represents a major project need and should be corrected. Human factors need to be incorporated into the design at this early design stage to ensure accessibility by the crew.

The Review Panel noted that a significant quantity of Government Furnished Equipment (GFE) must be supplied by NASA to the FCF prime contractor. Therefore, GFE is a substantial part of the FCF program and represents a significant risk to FCF cost and schedule. Several items of GFE such as the Active Rack Isolation Subsystem (ARIS), International Standard Payload Rack (ISPR), ISPR Outfitting Racks, Microgravity Rack Barriers, and Payload Rack Checkout Unit (PRCU) are delivered by JSC. These items and associated support need to be committed to by JSC and GRC. Schedules for GFE items and support must be defined that support the FCF integration and delivery. It is essential that roles and responsibilities between JSC, Boeing, GRC, and the prime contractor be identified and documented. In addition, hardware items being procured by GRC under contracts independent of the prime contract such as the Electrical Power Control Units, Water Flow Control Assemblies, and Space Acceleration Measurement System (SAMS) sensor heads are also GFE to the prime contractor.

3.0 REVIEW FINDINGS BASED ON CHARTER

Assessment of overall status of the project in relation to the success criteria. Identify the strength of the FCF Project and FCF Preliminary Design as well as any concerns that exist.

- The compliance of the FCF system design (flight and ground) with the science requirement envelope, FCF systems requirements and ISS requirements was presented and reviewed at the PDR. Although metrics were not presented, in general the review panel thought that the science compliance presentation was outstanding and indicated how the FCF could accommodate a wide range of fluids and combustion experiments planned for ISS. This is not to say that there are not unresolved requirement compliance issues. One particular area of concern is the approach chosen to define enveloping the science requirements (satisfying 80% of the basis experiments) which appears to be problematic, subject to variable interpretation and difficult to verify compliance. The FCF contractor has instituted a requirements tracking and management system that appears sound and should enable successful progression of the design. Also, the FCF has yet to process a number of exceptions to ISS requirements for the CIR, FIR and SAR, which the Panel encourages the Project to do as soon as possible.

- Functional and performance requirements of the FCF system are documented in an excellent fashion. The FCF rack specifications, ground segment specification and FCF-to-payload interface documentation need additional work before baselining, which the Panel is recommending be a priority of FCF following PDR. Also, some limiting FCF system requirements may need to be revisited (e.g., 2000 watt power requirement for the FCF system), which the Panel recommends happen as soon as possible following PDR.

- The proper level of testing was discussed and the overall test and verification approach was presented at high level. Several issues were raised on the fidelity of planned hardware for the qualification phase and the absence of test results. The NASA project management indicated that a separate test and verification review for all hardware would be held subsequent to the PDR. The PDR panel concurs with this plan. The panel recommends that the software/avionics test and verification approach (for both flight and ground systems) be included as a part of this review if possible.

- The Review Panel believes that the FCF design complies with appropriate design guides and standards, including safety and quality. Though the specific contents of FCF assurance plans were not reviewed by the Panel, they were summarized and included in a presentation of the FCF Project Plan provided during the PDR Executive Session. They seem to be adequate. Several panel members reviewed the FCF's safety integration process for payloads in a separate splinter meeting at the PDR and it also appears to be adequate. Several safety related issues were raised by the panel concerning venting of small amounts of liquid fuels and combustion chamber cleanup.

- The existence and compatibility of the physical and functional interfaces, including software are established for FCF at the PDR stage. The FCF to payload interface definition documentation needs additional work following PDR. Also, although FCF hardware interfaces with ISS appear to be adequately defined and documented, FCF software interfaces with ISS are currently undocumented, which the Panel believes needs to be addressed between the FCF PDR and CDR-level review for any of the FCF racks.

- Some of the special test equipment and ground support requirements have been determined for the FCF and were presented at PDR. However, the Panel felt that because FCF ground segment definition lag flight definition, additional effort is required in this area following PDR.

- The Review Panel was asked to evaluate the progress and technical adequacy of the FCF project, which appears adequate at the PDR stage.

- The top-level operational concept of the proposed FCF design was presented at PDR. However, additional effort is required by the FCF project and the prime contractor to address FCF system operation, rack operations, and operational requirements as well as the overall operations concept for FCF.

- The disposition of all past FCF review action items were presented to the Review Panel in the FCF Executive Session at the PDR. The Panel believes that all actions from the FCF Hardware Concept Review were adequately addressed and are closed. The Panel was satisfied that actions from the CIR Preliminary Design Review were adequately addressed, except for actions relating to ensuring adequacy of up mass and up volume allocations for FCF rack deployment to ISS and the approach for CIR combustion chamber cleaning/contamination control. These two concern areas are included as Requests for Action with this report so that all actions from FCF reviews prior to the FCF PDR can be closed.

- The adequacy of management plans (development approach, costs, schedule, risks) for FCF were reviewed by the Panel. The FCF Project Plan is complete in its fidelity and the depth of planning for the Project. It was indicated in the FCF PDR Executive Session that detailed, networked schedules for FCF development work are not yet complete and baselined. The Review Panel believes that such schedules are essential to manage a project of FCF's scope to successful completion should be completed and baselined as soon as possible, with regular reporting on progress versus schedule baselines and critical paths at regular status reviews.

Determine if the preliminary design will meet performance cost and schedule requirements.

- The panel believes that the schedule slip for the ISS program (Rev.E to Rev.F) needs to be reflected in the planning for the contractor. The panel has no reason to believe that the hardware cannot be delivered on time and within the proposed budget. The issue of performance is somewhat clouded by the confusing science requirements. Nevertheless, the Panel believes that the FCF will be a valuable research tool for the fluids and combustion science community.

Determine if an appropriate overall architecture has been established and identified.

- The panel thinks that the architecture and projects risks were identified and presented very clearly during the PDR. Excellent progress has been made in this regard.

Verify that all feasibility issues have been addressed and project risks identified.

- The panel believes that the FCF project office and the contractor have defined a complete list of feasibility and risk issues. Excellent progress is being made to eliminate items from the list.

4.0 FINAL RECOMMENDATIONS

Overall, the review panel evaluates that the FCF project is ready to proceed with the detailed design phase. Furthermore, the panel finds that the Project Plan is sufficiently mature and should be expeditiously reviewed and signed to establish a Program Baseline and provide the FCF with implementation authority to proceed. Overall, the panel thought that the FCF PDR review presentations were highly professional and contained much detail. The presentation covered all aspects of the overall as well as the individual rack designs and operations. Each of the three racks is a different stage of the design (conceptual, preliminary, and delta-preliminary). The Review Panel identified strengths and request for action (RFAs) based on the PDR Review. A total of 22 RFAs are submitted in this report. The weaknesses and RFAs reflect a consensus of the panel. There were a number of strengths noted by the panel and they generally fell into the categories of Mechanical/Thermal Design Excellence, user-friendly features such as modularity, commonality, and automation, as well as the use of state-of-the art engineering computational tools. The weakness noted by the report, and embodied within the RFAs, generally fell into the categories of non-hardware compliance (data handling, human factors, resource constraints), system engineering level concerns (operation, logistics, software, science traffic model) and scientific capability including the need for increased participation of the scientific community during the design process.

5.0 INDIVIDUAL PANEL MEMBER REVIEWS

5.1 Kenneth Adams' Report

In general, the PDR presentations on the System and its component sub-systems were very credible and were presented by obviously competent and knowledgeable personnel. The Project and contractor teams were very receptive to the Panel inquires and provided, in most cases, sufficient information for closure. I have presented no RFAs since the majority of my technical concerns are covered in those submitted by other members of the Panel. However, I will present three concerns, which I consider important, although I have chosen not to raise them to the RFA level.

5.1.1 Strengths

1. The total design concept including hardware commonality and modular design.

2. Obviously dedicated personnel working within a team concept.

5.1.2 Weaknesses

1. Lack of a definitive Government "insight" and surveillance process.

2. Lack of "partnering" with the science and user communities.

5.1.3 Concerns

1. It was not evident, during the discussions of the system and sub-system software, that the Government has in place an appropriate "insight" process to independently assess the adequacy of the software design to meet system requirements. Since FCF is a major GRC program, I feel that it is essential that the MRDOC Surveillance Panel require preparation of a software surveillance plan, which has been reviewed and agreed to by the GRC software engineering and software assurance communities.

2. While the contractor organizational infrastructure indicates a systems engineering function, no evidence was presented that processes and procedures were in place that governed its operation. While it was evident that the systems engineering organization has played a major role in the preparation of the verification documentation, I saw no evidence (e.g., integration panels, rack integration documents) that the systems engineering discipline was being formally employed during the design phase of the program. The systems engineering organization must take a more proactive role in the design function rather than serving as a clerical function with regard to requirements and verifications.

3. A formal technical presentation of the FCF systems safety was not a part of the PDR. While it is true that the project had completed all required major milestones for safety prior to this review, it was not acceptable to exclude presentation of the material to the Panel. The NASA Administrator has defined safety to be a primary concern of all Programs and, as such, should be treated as a significant subject during all reviews. During the week, a splinter meeting covering FCF safety was conducted where discussions of the technical detail were held to assess the sufficiency of the present FCF safety design. There are no safety design issues at present. However, the role of the GRC OSAT safety organization in the FCF process must be defined relative to approval authority.

5.2 James Driscoll/Carlos Fernandez-Pello's Combined Report

The material presented at the FCF PDR meeting was a thorough presentation of all aspects of the FCF design, and it indicated that careful design work has been conducted to achieve compliance with the science objectives. We are very impressed with the overall design of the FCF, particularly considering the constraints in size, weight, power, and budget imposed on its design. The FCF design is unique and is capable of providing a facility to accomplish good science with the planned experiments. The design well meets, in general, the objectives of providing a permanent installation to conduct microgravity research in fluids and combustion, and appears to provide sufficient flexibility so that the FCF will provide long-lasting value when future experiments are proposed. Some weaknesses are, however, perceived which need to be addressed. The FCF design team appears to be very capable and committed to correct these weaknesses and to provide the best possible facility.

It appears that the design provides complete compliance with five of the basis experiments (C1, C5, C6, C7, and C8) and compliance with significant risk with the other basis experiments. There are concerns that some risk, generally acceptable, is introduced by the following issues: limited power and thermal rejection available for the PI's hardware; gas flow rates requirements in experiments using the flow tunnel; clean-up of combustion products and their venting; lack of mounting holes for optical components in the optical bench; the limited data downlink rates; unknown level of jitter associated with the microgravity control system and acoustic disturbances.

The FCF design is clearly ready to proceed to the critical design phase.

5.2.1 Strengths

Herein we list the strengths without elaboration, as there is little need to expand upon them.

The design of the rack infrastructure is a good one. This is critical since the infrastructure is not easily changed on orbit. The combustion chamber is large enough to meet many scientific requirements. A sufficient number of optical/access ports are provided and the design of the diagnostic modules appears to meet the requirements for the science objectives. A strength of the design is the commonality of the diagnostic modules, and other major components, which makes it possible to arrange many combinations of the components to fit the needs of planned and future experiments. The data storage capabilities on orbit are impressive.

The gas supply system is well designed and is sufficiently flexible to allow researchers with exceptional gas supply needs to add additional bottles with PI hardware. Provision is made for clean-up of combustion products through filtering, and subsequent venting. The combustion chamber design has good capabilities for studying fuels in the gaseous, liquid, or solid phases. The windows provide optical transmission for a wide range of wavelengths in the IR, visible and UV, although future experiments may require PI-provided windows. The windows are sufficiently large to provide a reasonably large optical collection efficiency, which is critical for some experiments.

The design team has made impressive efforts to provide more than the minimum required capabilities in order to make the FCF valuable in the long-term. The team is well informed of new advances in the areas of data storage, lasers, and diagnostics and is including the most advanced hardware in the design. The design team has a good understanding of the research that is to be conducted and is guided by the overall objective to optimize the quality of the science.

5.2.2 Weaknesses

The weaknesses are described in more detail here, so that the desired corrective action can be easily understood and accomplished.

The design of the Combustion Integrated Rack (CIR) seems to be based primarily on the requirements of experiments conducted in a quiescent ambient (MDCA, SOFBALL, LSP). This is understandable since they are the ones with the most advanced design. It appears that most of the requirements of the follow-on experiments can be met as well. However, it is important that the facility be able to fully meet the requirements of some of the experiments that will follow, in particular the solid fuel combustion experiments.

The presentation provided several conflicting values of the power available for various subsystems, such as the rack and the PI hardware. The thermal analysis of the heat rejection capabilities through air and water seemed incomplete, and may need further analysis. The power heat rejection capabilities may limit the quality of science that can be conducted on the FCF. Efforts to reduce the power required by the rack and thereby increase the power available to the PI hardware, and to increase the heat rejection allowed to the PI's hardware, are of critical importance.

It is not clear that the FOMA design will meet the requirements of the experiments using a flow tunnel with high oxidizer flows. Bottle changes require rack power down, which will interrupt the experiments and will waste gas in the chamber. A more complete study of clean-up of products of combustion and real time venting appears necessary.

The presentation did identify the risk introduced by the limited rate at which data can be downlinked. However, the explanation that some of the images can be compressed by a factor of ten was vague. The science may be compromised by the image compression in some cases, while it may not be compromised in other cases. Although the limitation in downlinking is inherent in the ISS design, it did not appear that there has been enough interaction between the design team and the PIs concerning data compression.

The supporting capabilities of the SAR appear to be very limited, and mostly relegated to storage of equipment. Although we realize that ISS does not allow hard connections between racks, consideration should be given to request exceptions to allow fiber optics, or other hard connections, between SAR and CIR or FIR. This would allow the use of lasers or data acquisition systems to be installed in SAR and used to get data from the CIR or FIR experiments.

Another risk that was identified by the design team is that of potential disturbances caused if the performance of the ARIS system is not satisfactory, or if acoustic noise is excessive. Again, it did not appear that there has been enough interaction between the design team and the PIs concerning potential disturbances and their effect on the science.

There was not presented an adequate explanation of how solid particles would be cleaned from the chamber walls, windows and exhaust system. Solid products will be formed as products of combustion (such as soot) and will be introduced as seeding for flow visualization, LDV or PIV diagnostics. Other experiments will require a particle-free environment (for Rayleigh scattering or LIF diagnostics, for example). To prevent contamination of experiments, a method to clean all walls is needed.

Another weakness is that too many of the optical packages are designed to have manual focusing controls, which increases crew time required to make changes. More of the packages should have automatic focusing controls. While some PIs will not want automatic control, the presentation did not identify the wishes of the PIs and the potential risk associated with the need for extensive manual focusing, which depends on the experiment. The optical bench has limited use for future optical diagnostics because there are not enough mounting holes to install optical components. Also no laser water cooling, or nitrogen purge, is provided in the optical bench.

5.2.3 Concerns

One concern is that there appears to have been insufficient interaction between the design team and the various PIs at NASA and universities concerning design trade-off, power and cooling available, combustion products cleaning, venting, and other options. Some of these issues are complex and are hard to define and subsequently verify without interaction between the design team and the user community. Further inclusion of the user community (the scientists) in the verification test planning process and design reviews will increase the probability of ultimate success.

The FCF is well designed to meet the basic requirements of a majority of the basis experiments and their near-term science objectives, but there is some concern that long-term science objectives have not been adequately considered. Some effort in this direction is suggested.

5.3 Daniel Gauntner's Report

In general, the FCF team, both NASA and the Federal Data Corporation, presented a strong review of the subject systems that are being developed for the microgravity research to be conducted aboard the International Space Station. The presentations described the degree of accomplishment and the relative level of detail that have been achieved for the system and the related subsystems. The FDC has achieved a lot since taking over the project under the MRDOC contract.

The FCF System PDR was conducted in an environment of transition. Design activity performed under other contracts or previously by civil servants has been consolidated on the FDC contract. In a relatively short time, considering the complexity of the effort, FDC has done well to get to the current state. As one might expect, the systems PDR was at a lesser degree of completeness than the various subsystems. Within this context, the overall FCF design activity shows a number of strengths and weaknesses.

The contractor attempted to answer questions either real time or as soon after the questions as possible. One of the FDC folks provided me with an excel spreadsheet of the support equipment needed for the project. While extensive, the format and content of the list suggests that the contractor is still in the formative stages in this area. The list was not dated, nor did it have page numbers. Quantities in numerous cases were not specified. It was not possible to tell if the list was complete or current.

In conclusion, I want to thank the government and contractor team for an overall and frank review of the current state of the FCF design. Their continued dedication will assure the success of the effort.

The following items list the major strengths and weaknesses that I see in the current design state. Several of these are ongoing from the CIR PDR held in the Spring of 1999.

5.3.1 Strengths

1. The overall system architecture (modularity, single rack/triple rack functionality, predominantly tool free operation) addresses the need to reduce resource consumption and to be sensitive to future experiment design accommodations.
2. The FDC is showing early reliance on productivity enhancement tools (Pro-E, DOORS, PVCS) that will both reduce the risk of configuration errors and will provide accepted practices for design and management of requirements.
3. The use of fidelity mockups and assemblies for the development of experiment options and operations procedures allows early crew involvement in the facility design process and an early tool for science PIs to design their packages.

4. The degree of time that has elapsed from initiation of the FCF project (due largely to space station time extensions) has not impeded the designers from using state of the art diagnostics tools and IT systems. The modularity and open-ended architecture will assure updates of these systems before launch and after operations begins.

5.3.2 Weaknesses

1. The overall presentation of software development and management was weak. From the information presented some FCF sub-systems (e.g., avionics and software) are not all at the same level of development. The design of software versus software requirements was unclear.
2. A continuing concern involves the communication and connectivity between the PIs and the facility engineers. Repeated references to the degree that PIs knew of the facility requirements suggested continuing poor communications of realism to the PIs.
3. Configuration management and configuration control procedures are not visibly being practiced according to the released plan.
4. The project does not seem to be doing resources management (weights, power, scheduling).

5.3.3 Concerns

From the information presented during the FCF PDR, it appears that some FCF subsystems are not all at the same level of development. These include the avionics and software. Some relative immaturity is expected at this stage, but the project hasn't dealt with them in sufficient detail in its planning, from what I can see, to assure a greater mismatch problem doesn't arise later. The status of each subsystem and package should be assessed. Additional reviews should be held to assure relative uniformity in the maturity of the design. Software reviews should be held to assure adherence to design requirements, from an integrated systems level software design approach.

5.4 Glynn Holt's Report

Allow me to preface my remarks by saying that this facility design represents a superb platform for conducting microgravity fluid science experiments. My reason for emphasizing this is that my comments during the Review were uniformly critical, but only because time was short. I think I represent the U.S. microgravity fluid science community fairly when I say that we are eager to get the FCF on-board the ISS and begin running experiments! The entire team is to be thanked for putting together a very detailed review package and allowing "in-the-trenches" engineers to both present and answer questions.

One of the general comments I have is that there is a continuing need to increase quantity and quality of PI and Facility communications. This should include both current flight PIs as well as ground-based PIs. This is addressed in detail in RFA No. FCF-PDR-0015.

Related to the communication problem, the Science Requirements as expressed in the SRED are in many cases ill-defined, and that fact combined with the Contractors Compliance Matrix response allows several issues of importance remain unresolved. For example, there is a requirement of 5 experiments per year throughput – there is no realistic evaluation of this requirement in terms of data management, operations and resource allocation, yet the compliance matrix records a "Yes" for meeting that requirement. NASA must revisit the SRED requirements with a view to redefining and revising several murky requirements in order to facilitate finalization of the design. This needs to happen before CDR.

5.4.1 Strengths

One of the primary strengths from the PI's standpoint is the flexibility and modularity of the design. Several alternatives exist for configuration of experiment packages, with redundancy and interchangeability.

A near state-of-the-art complement of diagnostics, coupled with a commitment to upgradeability, exists to make this facility unequaled in its capability to accommodate a wide variety of fluids experiments.

The design allows for ease of interface, acquisition and control (hardware and software) for PI-supplied equipment such as special cameras, translation stages, etc.

The SAR and FIR compatibility is a big positive – it will allow many more experiments to be accommodated without requiring the engineering work to make something designed for the FIR, SAR-compatible and vice-versa.

The commitment to all-digital handling/storage of image data is a positive, even though it leads to problems of data management. But it is a fact that image data these days does not get analyzed before first being digitized, thus this decision removes the burden of image digitization from the PI.

5.4.2 Concerns

A management plan for science image data (often the PI's only data) coordinating storage, potential compression and/or downlink is not firmly in place. As of the moment, the storage and downlink requirements are NOT met by the FCF. There is of course a general recognition of this fact, but there is a sense that, in the end, real-time operational work-arounds will solve the problems we can't solve today. My view is that Ops work-arounds should be reserved for handling real-time opportunities or crises, which will inevitably arise during any mission.

Closely related, the FCF needs to DEFINE several image data compression algorithms and present those to the PI community as soon as possible. Likewise, the FCF needs to DEFINE a baseline storage capability and a baseline downlink capability. When these items are presented in a timely fashion to the PI's, the burden will be on the PI's to then define a data management plan which takes advantage of the flexibility afforded by the FCF. But as of the moment, there are TOO MANY UNKNOWNS for a PI to make informed data management decisions.

Once again, closely related to this issue is the fact that the FCF, once compression algorithms are defined, must TEST, WITH EACH CAMERA and representative images, the compression algorithms. Alternatively, at a minimum, the FCF must provide each PI with the algorithms and facilities to allow them to conduct their own tests to determine acceptability. The majority of PIs will not be able to predict the effect of a particular compression scheme on their type of data – they must see tests, with resulting spatial and depth resolutions.

The above 3 concerns are expansions of the concern which prompted RFA No. FCF-PDR-008.

The temperature environment on the optical bench is NOT compatible with normal test chamber stability (nominally plus/minus 1 degree for entire test chamber) and range requirements for lab experiments. This means that EVERY PI will be forced to provide his own constant temperature control bath/system. This includes the majority of PIs whose experiments will only need near-ambient temperature at the test chamber (but with plus-minus 1 degree stability for the entire test chamber). Clearly cryogenic and high-temperature experiments will be provided by those “extreme” PIs. But since every PI will need constant temperature control, it is felt that the FCF facility should provide a quick-disconnect hook-up to a facility-provided, near-ambient constant-temperature bath, similar to a typical CT bath found in a ground-based laboratory. RFA No. FCF-PDR-016 addresses this issue.

There is currently no capability for pulsed illumination on the facility. The SRED has several requirements regarding PIV capability, but the lack of pulsed illumination will severely impact the facility's ability to provide PIV capability. Also, in general, pulsed illumination is commonly used in a variety of imaging scenarios apart from PIV. RFA No. FCF-PDR-017 addresses this issue.

The choice of cPCI bus for PI-provided hardware expansion (A/D, control, lock-in amp, etc.) may limit PIs in terms of commercially available boards. Further, drivers for available boards may not be available for the VxWorks operating system. This issue needs to be addressed by the facility in order to ensure that this envisioned flexibility remains a viable option for PIs. RFA No. FCF-PDR-018 addresses this issue.

The specific cameras identified leave some room for improvement:
- For example, the current "High Resolution" camera has only 1024 x 1024 pixel capability. Current commercial CCDs within reasonable budgets BEGIN with 1300 x 1300 pixels, and 2048 x 2048 and even 4096 x 4096 to be considered "high resolution."
- The "Ultra-High Frame Rate" camera is only 1000 frames per second. There exist several commercially available cameras with 10,000 fps with a high degree of versatility and small package. Even 100,000 fps and upwards can be achieved for digital media (non-film). Though there is no RFA that specifically addresses this issue (largely since the SRED is not well-defined on this point), the project should carefully consider choices of such critical diagnostic hardware, and where appropriate reevaluate specific choices which do not present any significant additional cost.

5.5 Robert Jenkens' Report

The Fluid Combustion Facility Preliminary Design Review was successfully conducted during February 12-16, 2001. This report provides a summary of strengths, observed weaknesses, along with several specific concerns, which have been formally documented as Request for Actions (RFAs). The FCF preliminary design, pending successful resolution of the identified open items, is evaluated to comply with program objectives and is recommended to receive approval to proceed into the critical design phase.

5.5.1 Strengths

These items are highlighted as observed strengths:

1. The FDC development team demonstrated a thorough understanding of the FCF requirements, and exhibited a high degree of confidence and competence.

2. Both the GRC and FDC Project Management teams were well organized.

3. The planned use of common hardware components is evaluated as a benefit and provides an opportunity for increased payload operations flexibility.

4. The use of computer aided design and requirements trace software tools (Pro-Engineer, DOORS) and web-based documentation are positives.

5. FDC and GRC Projects have performed a lot of work to understand where the major concerns reside and provided a thorough assessment at the PDR. Although differences exist on how the issues should be addressed, there appears to be a common agreement on the areas of concern.

6. The fixed price contract type is assessed to be a strength – the nature of developing a facility lends itself to continuing requirements evolution, constantly striving for additional capability. This type of contract will serve as a forcing function to resolve issues in a timely manner and keep the development progressing.

5.5.2 Weaknesses

The following items were identified as weaknesses or areas of potential concern within the preliminary design:

1. Lack of firm, verifiable requirements in several fundamental area and large percentage (~12%) of unresolved compliance items. The approach chosen to define enveloping science requirements (satisfy 80% of basis requirements) appears to be problematic, subject to variable interpretation, and difficult to verify compliance.

2. Government Furnished Equipment (GFE) delivery schedules appear “soft” and technical development is necessary on at least one unit to achieve a critical microgravity science requirement. A significant risk resides in the fact that the FCF Project does not directly manage each of the GFE items and is dependant upon other NASA contracts to meet cost, schedule, and technical requirements.

3. The degree of incomplete design analyses represents a potential risk for unanticipated results and late identification of design impacts. For example, the radiation analysis could identify the need for spot shielding or alternate part selection to satisfy mission life requirement – this result would further aggravate the weight issue or delivery schedule respectively.

4. The software design processes as presented, appear to be well understood by the contractor. However, insufficient information was presented to permit a design compliance assessment.

5. An end-to-end operations concept is immature and could have design impact when details are fully developed. This represents a risk to program cost and schedule or could result in constraints to PIs.

5.5.3 Concerns

1. Mass properties are recognized to have insufficient margin and identified as a major risk. However, no specific details or actions were presented to resolve the issue. A review of the FCF Mass Properties Control Plan yielded several additional concerns. The plan does not show what articles have controlled masses (component, subsystem, and system) versus assemblies that may allow uncontrolled tracking of mass among their constituent parts. Also, no evidence was presented to show the mass and c.g. control procedures are being followed. The contractor also has not fully investigated the margin associated with the GFE items. (Currently carrying zero margin.)

2. The CIR/FIR/SAR optical bench design contains recessed electrical connectors without provision for on-orbit replacement. No requirement has been derived for the number of mate/de-mates over the 10 year mission life or to accommodate repair of a damaged connector.

3. The CIR/FIR/SAR design identified a number of requirements that will need exceptions to be granted. Until the exceptions are approved or rejected, the design compliance will remain unresolved and represents an unquantified technical and programmatic risk.

4. The FCF software development environment is being developed and utilized by the Exhibit 1 contractor to develop, validate, and deliver the initial operational build of software. However, during the PDR discussions, it was identified that the development environment is not a contractually required deliverable item under the Exhibit 1 contract. Furthermore, it is unclear how the Exhibit 2 contract/contractor, which has the responsibility for lifecycle maintenance and enhancement of FCF software, will acquire the necessary software development environment.

5.6 Michael Miller's Report

The FCF PDR was well organized; I especially liked being able to review the documentation from the website prior to the meeting. The briefing packages were well done and the graphics were helpful in understanding the design implementation. The participants acted in a friendly and professional manner. The design and associated documentation was of sufficient detail for what is expected at a PDR.

In summary, although the FCF has several challenges and issues to resolve, it has made sufficient design progress that it is my recommendation to grant authority to proceed. It would be wise to baseline the specifications and ICDs quickly following the completion of the PDR.

5.6.1 Strengths

1. PDR data was available from website, which greatly facilitated review of the materials.

2. Modular design that allows swapping components and diagnostic packages among FCF's 3 racks.

3. Optics bench design seems to be a good idea – it allows easy crew access to install hardware without having to rotate a rack. This will save considerable crew time since ARIS adds about _ hour to prepare a rack for rotation.

4. Door design seems to be a good idea – it allows containment for fire suppression and also will help provide acoustic dampening.

5. Ground mockup was useful in evaluating the design concepts for the CIR and FIR; it allowed me to see where there might be potential design problems as documented in RFA No. FCF-PDR-006.

6. The design appears to be reserving sufficient bandwidth in the IOP's internal 1553 bus to accommodate ARIS acceleration measurement data.

5.6.2 Weaknesses

1. Some known requirement exceptions have not yet been submitted (example: rack to rack cabling).

2. Planned payloads want to collect and downlink too much data, resulting in massive hard disk changeout.

3. GFE items, schedule, and associated support is insufficient at this time, including GFE under JSC control such as ARIS, ISPRs, ISPR Outfitting Kits, PRCU, etc. – see RFA No. FCF-PDR-004.

4. No credible plan for cleaning the CIR combustion chamber exists. This should be presented to the PSRP to ensure that no FOD gets into the cabin and that the cleaning solvents are acceptable.

5. Due to the nature of the SRED requirements to accommodate 80% of the proposed experiments, it seems likely that the FCF will encounter "requirements creep," with associated cost growth. At some point in the near future, specific, verifiable requirements should be documented and the 80% requirement deleted.

6. Conceptual design of SAR when populated with middeck lockers does not appear to be feasible from a packaging and utility routing perspective.

7. Extra effort needs to be focused upon the planned interface to the Station SCS laptop since FCF is the first payload to utilize this concept.

8. Vacuum venting for the CIR needs additional evaluation for the various operational scenarios and the effect on VES valve life, frequency, microgravity performance during flowthrough experiments, potential CMG saturation issues, external payload impacts/timelining.

5.7 Heide Stefanysun-Piper's Report

The briefing package presented at the FCF PDR was well organized and very thorough. The design concept for the three racks appears to optimize the ability to conduct experiments with minimal crew interaction.

5.7.1 Strengths

1. Commonality – The FCF makes extensive use of common components between the three racks. There are many benefits this approach. Crew will be more familiar with similar components, and reduce the required training time, a limited resource. Common components should also translate into fewer spare parts, thereby reducing the stowage requirements.

2. Modularity – The modular design of the diagnostic equipment allows for flexibility for various experiments. This design also will make it easy to upgrade equipment as new technologies emerge.

3. "Tool-less" – The innovative design of the diagnostic packages has resulted in the ability for the crew member to assembly the packages without the use of tools. This feature allows for optimal use of the crew's time on orbit in ease of assembly. Because the packages can be assembled without the use of tools, special tools do not need to me manufactured and manifested, reducing stowage requirements.

4. Use of the SSC (Station Support Computer) – Use of the SSC for crew interface is unique and innovative. By using a resource that is already on-board, minimizing the need to manifest an additional laptop computer.

5.7.2 Weaknesses

1. Data – The amount of data that is generated and requested for downlink does not appear to be supported by the current on-board systems.

2. Principal Investigator (PI) requirements - The needs of the Principal Investigator do not appear to be included in the Facility requirements for resources (power and stowage). These areas need to include all requirements and not just the facilities.

5.7.3 Concerns

1. Integrated Concept – The integration of all three racks needs to be considered. When power, data, crew time, stowage, and spares are discussed, it is always in terms of a single rack. Based on the experiments presented, the three racks will have to be operated concurrently, and an integrated operations concept needs to be developed.

2. Exceptions to Requirements – Any requirements that will require exceptions or waivers need to be addressed early, so that they can be reviewed to minimize the impact on the facility design. This includes human factors requirements that can not be met.

5.8 Irene Taylor's Report

The FCF PDR presentations were conducted in a professional, informative manner. Technical presenters were well prepared, and management representatives readily fielded the programmatic questions. Engineering and design support personnel were in attendance, and provided immediate response to resolve most of the questions from the panel, without the need for numerous follow-up splinter sessions. Panel questions and RFAs documentation support was timely, accurate, and provided by friendly personnel.

The Prime contractor, which has been on-board for approximately 10 months, retained many of the personnel from the previous support contract. The management structure is well organized, with apparently healthy design team interactions. The contractor demonstrated a clear understanding of the technical issues and risks.

In general, the FCF design has progressed well beyond the PDR level. The modularity and commonality of components within the three racks were key features to the design, enabling some of the more mature design elements in the CIR to be utilized in the FIR and SAR designs. Assessments of compatibility between the facility design and representative experiments' requirements were incorporated throughout the presentations.

While there remain open requirements concerns to be addressed, in my assessment the FCF design and this team are ready to proceed.

5.8.1 Strengths

The commonality and modularity of the components provides benefits in several areas, including design, development, testing, training, and a reduction of on-orbit common equipment spares between the 3 racks.

The contractor has instituted a requirements tracking system to ensure requirements flow down and verification traceability.

The design demonstrates a proactive approach toward resolution of acoustic concerns, which are prevalent for payloads and facilities on the ISS.

A systematic method has been incorporated for identifying programmatic and technical risks. The risk tracking system includes classification of probability and consequences of the risk, with associated action plan to mitigate the risks.

The contractor is cognizant of advances in data storage devices, and is incorporating the ability to upgrade within the basic design.

5.8.2 Weaknesses

Projected data quantities for on-board storage, and for downlink to experiment teams, are not accommodated by the FCF design. Data reduction and video compression schemes should be special emphasis topics in detailed discussions with actual PIs.

In the compliance matrix, some of the assessments indicated that FCF met particular needs of the basis or real experiment, when actually the need was met only if the individual payload provided additional capabilities.

Operations analyses and end-to-end data flow assessments have not been performed. Integrated operational assessments of all on-orbit and ground resources utilized by the FCF are needed. The ability to meet the utilization rate of 5 combustion and 5 fluid experiments per year cannot be adequately assessed, particularly if resources, design limitations, or operational constraints prohibit simultaneous operations of the CIR and FIR.

Manual alignments or adjustments will be required for some cameras or diagnostic packages. The operational details were vague, in relation to procedures and timing, and an estimated frequency of utilization of the crew-alignment packages was not presented.

5.8.3 Concerns

The contractor assumed compliance with some requirements based on exceptions or waivers that have not been submitted.

Answers provided from team members conflicted in terms of the interfaces to be tested utilizing the PRCU during integrated testing of the CIR GUI with the FIR Flight Unit, and the subsequent on-orbit interfaces between the CIR and the FIR, prior to arrival of the SAR.

While not widespread, there was some perceived confusion in roles and responsibilities between the contractor and the Civil Service with respect to the Prime contract, particularly in the area of safety. Plans for handling the verification and closeout of open safety items, without re-opening unrelated portions of combined Hazard Reports, should be resolved between the Civil Service and contractor.

The ground support for integration and testing of experiments should be evaluated to determine the minimum acceptable complement of equipment to meet reasonably expected experiment rates, based on type and complexity.

Knowledge capture should be addressed. Design engineers may not be available after the initial check-out period, and this facility is intended for multi-year operations.

APPENDIX A - FCF PDR REVIEW PANEL DESIGNATION MEMO

January 25, 2000

6700 (02-01)

TO: Distribution

FROM: 6700/Deputy Chief, Microgravity Science Division

SUBJECT: Appointment of Review Panel for the Preliminary Design Review of the ISS Fluids and Combustion Facility

The ISS Fluids and Combustion Facility Preliminary Design Review (PDR) will be held February 12-16, 2001 in Cleveland, Ohio. The review will consist of an overall preliminary design review of the FCF system, a delta-PDR for the FCF Combustion Integrated Rack, a PDR for the FCF Fluids Integrated Rack and a Conceptual Design Review (CoDR) for the FCF Shared Accommodations Rack, as follows.

- FCF System Preliminary Design Review – February 12-13 th
- FCF Combustion Integrated Rack Delta PDR – February 13 th
- FCF Fluids Integrated Rack PDR – February 14 th
- FCF Shared Accommodations Rack CoDR – February 15 th
- FCF PDR Executive Session – February 16th

The FCF design reviews on February 12-15th will be held at the Cleveland Marriott Airport Hotel at 4277 West 150th Street in Cleveland, Ohio. The FCF PDR Executive Session on February 16th will be held at the NASA Glenn Research Center in Building 500, Room 3102. The agenda for the review and review materials for the PDR are available at the FCF PDR website at http://www.grc.nasa.gov/WWW/fcf/pdr.

The FCF PDR Review Panel will consist of the following persons:

Chairperson:	Thomas L. Labus (NCMR)
Safety/Product Assurance:	Kenneth A. Adams (GRC)
Fluid Physics Science:	Glynn Holt (Boston University)
Combustion Science:	James Driscoll (University of Michigan)
	Carlos Fernandez-Pello (UC-Berkley)
Engineering:	Daniel J. Gauntner (GRC)
Project Management:	Robert W. Jenkins (GSFC)
Human Factors:	Heide M. Piper (JSC)
Operations/Integration:	Irene E. Taylor (MSFC)
ISS Technical:	Michael D. Miller (JSC)

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RE: 02-01
January 26, 2001

The FCF PDR will follow GRC project implementation review policy and guidelines in GRC-W6000.002. Per this guide, the Review Panel is chartered to evaluate the FCF design, identify any concerns and recommend any actions to be taken to enhance the probability of success of the Project. The Review Panel will also recommend whether the FCF Project is ready to proceed with the detailed design phase and whether the FCF Project Plan is sufficiently mature to baseline with a request for FCF flight implementation Authority to Proceed (ATP) from the Microgravity Research Program. In accordance with the above guide, the Review Panel will prepare and submit to me a summary report of its findings and Requests for Action (RFA) from the review within four weeks following the conclusion of the review.

Stephen N. Simons
Deputy Chief,
Microgravity Science Division

Distribution:
0500/K. A. Adams
7800/D. J. Gauntner
GSFC/R. W. Jenkins
JSC/M. D. Miller
JSC/H. M. Piper
NCMR/T. L. Labus
Boston University/G. Holt
UC-Berkley/C. Fernandez-Pello
University of Michigan/J. F. Driscoll

cc:
NASA HQ/E. Trinh
NASA HQ/B. Carpenter
NASA JSC/R. Nygren
NASA JSC/M. Culp
NASA MSFC/R. Henderson
NASA MSFC/W. Ramage
0612/K. Brocone
6700/R. Corban
6700/F. Kohl
6700/J. Salzman
6700/T. Sutliff
6700/R. Zurawski
6724/T. St. Onge
7800/D. Rohn
FDC/G. Bluford
FDC/C. Pestak
FDC/M. Korba

APPENDIX B – FCF PDR INVITATION LETTER

January 16, 2000

6700 (01-01)

TO: Distribution

FROM: 6700/Microgravity Science Division

SUBJECT: ISS Fluids and Combustion Facility Preliminary Design Review

The ISS Fluids and Combustion Facility Preliminary Design Review (PDR) will be held February 12-16, 2001 in Cleveland, Ohio. The agenda for the review is listed below (Enclosure 1):

- FCF System Preliminary Design Review – February 12 – 13, 2001
- FCF Combustion Integrated Rack Delta PDR – February 13, 2001
- FCF Fluids Integrated Rack PDR – February 14, 2001
- FCF Shared Accommodations Rack CoDR – February 15, 2001
- FCF PDR Executive Session – February 16, 2001

The design reviews on February 12-15th will be held at the Cleveland Marriott Airport Hotel at 4277 West 150th Street in Cleveland, Ohio. Attendance these days of the review are open to everyone. On February 16, 2001, there will be a FCF PDR Executive Session at NASA Glenn Research Center. This session is limited to invited Program/Project participants and the PDR Review Panel. All individuals who plan to attend the review need to notify Ms. Kimberly Wells by Friday, February 2, 2001. Please fill out Enclosure 2 and email it to kimberly.a.wells@grc.nasa.gov.

A Welcome Reception will be held after the FCF PDR on Monday, February 12th at 6:00 p.m. at the Marriott Hotel. The tickets for the reception will be $10 (US dollars) per person. Please indicate on your notification form (Enclosure 2) whether or not you plan on attending the Welcome Reception. Tickets will be held for out of town individuals who plan on attending. However, payment is due the first day of the review. There are a limited number of tickets available on Monday, therefore, advanced reservation is requested.

Location information on the Cleveland Airport Marriott Hotel and the NASA Glenn Research Center is provided in Enclosure 3. A block of rooms has been reserved at the Cleveland Airport Marriott Hotel for out-of-town participants. A room rate of $86 (US dollars) per night is available.

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RE: 30-01
January 16, 2001

For reservations, please contact the Marriott Hotel at (216) 252-5333 or toll free (800) 228-9290 in the United States and Canada. Please indicate that you are attending the FCF PDR when making your reservation.

If you need any additional information pertaining to the logistics of the FCF PDR, please contact Ms. Kimberly Wells at 216-433-2855 or by e-mail at kimberly.a.wells@grc.nasa.gov.

(signed electronically)
Robert L. Zurawski
FCF Project Manager

cc:
HQ/B. M. Carpenter
HQ/R. Crouch
HQ/M. K. King
HQ/G. Pitalo
HQ/J. L. Robey
HQ/E. H. Trinh
JPL/R. G. Beatty
JPL/U. Iraelsson
JPL/J. F. Pensinger
JSC/M. A. Culp
JSC/D. W. Hartman
JSC/R. W. Nygren
JSC/N. R. Pellis
JSC/N. J. Penley
JSC/C. Spease
JSC/J. H. Temple
MSFC/L. Baccei
MSFC/M. E. Boudreaux
MSFC/R. D. Geveden
MSFC/R. Henderson
MSFC/J. W. Poe
MSFC/W. E. Ramage
MSFC/D. A. Schaefer
MSFC/R. A. Schlagheck
MSFC/J. E. Sykes
ASI/Jean Sabbaugh – Italy
CNES/Bernard Zappoli - France
CSA/Robert Hum - Canada
DLR/Rainer Kuhl – Germany

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cc (continued):

ESA/ESTEC/Marc Heppener - Netherlands
ESA/ESTEC/ Guiseppe Reibaldi - Netherlands
INPE/Iraja Bandeira - Brazil
National Development Agency/Shinichi Yoda - Japan
Russian Academy Science/Y. Osipiyan -

APPENDIX C - ACRONYMS

Acronym	Description
A/D	Analog to Digital
ARIS	Active Rack Isolation System
c.g.	center of gravity
CCDs	Charged-Coupled Device
CDR	Critical Design Review
CIR	Combustion Integrated Rack
CMG	Control Moment Gyro
COTS	Commercial Off The Shelf
cPCI	compact Peripheral Component Interconnect
CT	Constant Temperature
DOORS	Dynamic Object Oriented Requirements System
DWG	Discipline Working Group
EPCU	Electrical Power Control Unit
FCF	Fluids and Combustion Facility
FDC	Federal Data Corporation, Inc.
FIR	Fluids Integrated Rack
FOMA	Fuel/Oxidizer Management Assembly
fps	frames per second
GFE	Government Furnished Equipment
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
ICDs	Interface Control Documents
IOP	Increment Operations Plan
IR	Infrared
ISPR	International Standard Payload Rack
ISS	International Space Station
IT	Information Technology
JSC	Johnson Space Center
KSC	Kennedy Space Center

Acronym	Description
LDV	Laser Doppler Velocimetry
LIF	Large Isothermal Furnace
LMM	Light Microscopy Module
LSP	Laminar Soot Processes
MDCA	Multi-User Droplet Combustion Apparatus
MRDOC	Microgravity Research Development and Operational Contract
MRPO	Microgravity Research Program Office
MSD	Microgravity Science Division
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NCMR	National Center for Microgravity Research
OSAT	Office of Safety and Assurances Technologies
PDR	Preliminary Design Review
PI	Principal Investigator
PIV	Particle Image Velocimetry
PRCU	Payload Rack Checkout Unit
Pro-E	Pro-Engineer
PSRP	Payload Safety Review Panel
RFAs	Requests For Action
RIDs	Review Item Discrepancies
SAMS	Space Acceleration Measurement System
SAR	Shared Accommodations Rack
SOFBALL	Structure of Flame Balls at Low Lewis-Number
SRED	Science Requirements Envelope Document
SSC	Station Support Computer
SSPO	Space Station Payloads Office
TBD	To Be Determined
US	United States
UV	Ultra Violet
VES	Vacuum Exhaust System
WFCA	Water Flow Control Assemblies

APPENDIX D - REVIEW PANEL REQUESTS FOR ACTION (RFAs)

FCF-PDR-001 - FCF Software Development Environment

Statement of Concern

The FCF software development environment is being developed and utilized by the Exhibit 1 contractor to develop, validate, and deliver the initial operational build of software. However, during the PDR discussions, it was identified that the development environment is not a contractually required deliverable item under the Exhibit 1 contract. Furthermore, it is unclear how the Exhibit 2 contract/contractor, which has the responsibility for lifecycle maintenance and enhancement of FCF software, will acquire the necessary software development environment.

Recommended Action

Evaluate the Project's requirement for a FCF software development environment, and develop an approach to satisfy the need.

FCF-PDR-002 - FCF Metrics

Statement of Concern

Minimal metrics were presented at the FCF PDR to provide an overall measure of the project status and the rate of progress. This could include: Percentage drawings, lines of code of software, TBDs in ICDs, science requirements, development hardware risks, weight, RID closure, etc.

Recommended Action

Start utilizing project metrics so that progress can be measured and issues can be identified in the process of reaching the CDR milestone.

FCF-PDR-003 - Software/Avionics Review

Statement of Concern

Software and avionics is imbedded within each of the rack product teams. Only a top-level software architecture was presented at the PDR. No formal system level reviews are planned. Software and avionics architectures and status were not presented to any level of detail at the PDR. Concern was raised on the progress made to date. No formal system review of the software/avionics is planned.

Recommended Action

Schedule a stand-alone informal avionics and software review for the FCF. This review should include the approach to verification. This review should include flight, as well as ground systems.

FCF-PDR-004 - GFE

Statement of Concern

GFE is a substantial part of the FCF Program and there is significant risk associated with GFE to the FCF cost and schedule. Several items of GFE such as ARIS, ISPR, ISPR Outfitting Kits, Microgravity Rack Barriers, PRCU are under JSC control and these items and associated support need to be committed to by JSC and GRC. Schedules for GFE items and support must be defined that support FCF integration and delivery. Roles and responsibilities should be identified and documented between JSC, Boeing, GRC, and FDC.

Several RIDs on GFE were also rejected by the FCF contractor at the FCF PDR. These should be evaluated by GRC.

Recommended Action

Document agreements on GFE delivery and support between JSC, GRC, Boeing, and FDC, including detailed schedules and a work plan for support. Evaluate RIDs on GFE that were submitted at the PDR.

FCF-PDR-005 - ARIS RS-232 Interfaces

Statement of Concern

FCF rack designs do not provide RS-232 interface at the front of the rack per the CR5057 update to SSP 57005 ARIS to Payload ICD.

Recommended Action

Incorporate RS-232 interface per SSP 57005 for ARIS.

FCF-PDR-006 - Potential ISPR to FCF Interferences

Statement of Concern

Presentations and supporting PDR documentation did not fully address all packaging concerns. These include: (1) Rack doors and ARIS snubbers - does the door clear the snubbers when opened? (2) ISPR center post fittings and optics bench and avionics boxes - does the optics bench clear the center post fittings on top; do AV boxes fit with center post fittings on bottom? Reference drawing 683-50184. (3) Human factors keepout envelopes were not defined for connectors on optics bench or for PI power/thermal; space between PI packages not defined to allow crew installation. (4) Internal ARIS cable harness for 4 post configuration. (5) Rack maintenance switch location. (6) Accumulator and launch restraints. (7) ARIS accelerometers - do they interfere with FIR/SAR optics bench?

Recommended Action

Model all hardware in 3D CAD to ensure no interferences exist. Add requirements to the IDDs that define keepout envelopes to allow crew access to connectors and packages for installation and removal.

FCF-PDR-007 - Human Factors - Access to All Connectors

Statement of Concern

When the rack is populated to the maximum science volume, it is unsure if sufficient access is available for connector access (i.e., gas and water), which need to be connected with the bench in the stowed position. Also, depending on the height and amount of science packages, can the bench be accessed for attachment mechanism, cable routing, etc.

Recommended Action

Ensure that human factors requirements are met to ensure that connectors and mechanisms are accessible by all crew members.

FCF-PDR-008 - Data Handling Requirements Not Clearly Defined

Statement of Concern

Experiment data requirements severely exceed the stated capabilities of the FCF. The project requirements concerning data handling do not appear to be a verifiable design parameter. Methods proposed for capturing and downlinking data are not sufficient for many of the representative experiments. Data system compliance to requirements is not demonstrated for many of the “yes” responses in the compliance matrix. Compression and data reduction schemes should be advertised capability, but they are only viable to the PIs which accept the resulting products when compared to original source data. Requirements for FCF command and telemetry throughput, including data storage capacity, real-time data available to the PI (at TSC) during the test, and maximum allowable data latency are not adequately defined. Significant technical, schedule, and cost risk exist to the FCF contractor, the government, and the PI, due to the requirement ambiguity. A design compliance assessment is not possible until the requirements are definitized and a corresponding hardware design and operational concept is produced.

Recommended Action

(1) Clarify the FCF requirements for command and data handling. (2) Preliminary analysis of command and telemetry throughput is needed, including PI interaction on decisions to proceed with subsequent sample runs. (3) Update the FCF hardware and operations design to accommodate the definitized requirements. Conduct a delta design review to assess compliance.

FCF-PDR-009 - Configuration Management System

Statement of Concern

The contractor system for configuration management (CM) was inadequately shown. Philosophies for the baselining of project products (designs, documents, drawings) were insufficiently explained to determine when the project plans to put items under CM (change control, version update procedures, adequate dating and numbering). Project personnel did not appear to be sufficiently knowledgeable about CM plans to assure proper command and control in the future. Examples: PDR review documents were described as “controlled documents,” yet pages were not dated. Common hardware show different values between documents (ARIS weighs 75.5 or 75.6 lbs. for CIR or FIR).

Recommended Action

(1) Complete CM philosophy and planning document according to accepted ISS practices. (2) Train project personnel on its use and applications. (3) Apply to controllable items.

FCF-PDR-010 - Cleanup of Research Environment

Statement of Concern

Soot particulates, solid combustion particulates and colloidal microparticles may coat the windows and exhaust ducts, and may contaminate future experiments. A procedure is needed to clean the walls.

Recommended Action

Identify hardware/procedures to clean windows, exhaust ducts.

FCF-PDR-011 - Periodic Re-Calibration

Statement of Concern

To maintain the accuracy of flow metering, spatial positioning, etc. of components on the CIR and FIR, periodic recalibration will be needed. Comment on how this would be done.

Recommended Action

Identify hardware/procedures needed in the FIR and CIR designs that would accommodate future recalibration.

FCF-PDR-012 - FCF Design Changes from ARIS Alterations

Statement of Concern

The integrated discussions of the ARIS system have indicated a number of changes that may/will be needed for the overall/common design. Impacts due to these changes on the mass properties and thermal control systems have not been quantified. Given the closeness of today's performance estimate to current controlled resource limits, a less-than-timely accommodation of these changes make impact performance and delivery considerations.

Recommended Action

(1) Clarify contract-versus-customer responsibilities for all aspects of the ARIS. (2) Generate risk impacts (detailed/quantitative) for the various changes. (3) Systematically consider ARIS impacts as other design needs are fulfilled (e.g., rack to rack cabling, ORU changeouts).

FCF-PDR-013 - Mass Properties Control Plan

Statement of Concern

Mass properties are recognized to have insufficient margin and identified as a major risk. However, no specific details or actions were presented to resolve the issue. A review of the FCF Mass Properties Control Plan yielded several additional concerns. The plan does not show what articles have controlled masses (component, subsystem, and system) versus assemblies that may allow uncontrolled tracking of mass among their constituent parts. Also, no evidence was presented to show the mass and c.g. control procedures are being followed. The contractor also has not fully investigated the margin associated with he GFE items. (Currently carrying zero margin.)

Recommended Action

(1) NASA/FCF project review and confirm mass requirements; (2) FCF contractor to revise Mass Properties control plan to adopt an explicit approach for mass and c.g. control; update the CIR/FIR/SAR mass properties tables; implement and aggressively execute the plan to mitigate the risk and ensure requirements are achieved; conduct study to identify potential mass savings through redesign or material changes.

FCF-PDR-014 - Optics Bench Electrical Connector Design Life Accommodation

Statement of Concern

The CIR/FIR/SAR optical bench design contains recessed electrical connectors without provision for on-orbit replacement. No requirement has been derived for the number of mate/de-mates over the 10 year mission life or to accommodate repair of a damaged connector.

Recommended Action

Evaluate the optics bench electrical connector design versus the 10 year life requirement. Modify the connector design as necessary.

FCF-PDR-015 - Facility and PI Technical Communications

Statement of Concern

Several particular issues have highlighted a deficiency in the two-way communication between PIs and Facility. These issues are: (1) Data storage compression and resources: media capacity, compression scheme(s) are not defined, and current storage/downlink solutions do not meet PI requirements without compression. (2) Considering the larger (particularly fluids) pre-flight PI community, the lack of pulsed light sources represents a deficit in fundamental diagnostic capabilities. (3) The temperature environment does not meet PI requirements. Currently, ALL “basis" and “real" experiments will require PI to provide own temperature controlled for test chambers to meet requirements. Future PIs will encounter the same problem.

Recommended Action

(1) Facility should prepare brief communication to PIs (flight and ground) addressing at least issues 1-3, and current FCF solutions and requesting more detailed input from PI community. (2) Yearly PI/Facility meetings should be scheduled to assess issues such as above. Meetings should be open to all program PIs and not limited to flight PIs.

FCF-PDR-016 - Constant Temperature at Payload Test Chamber

Statement of Concern

The temperature environment at the test chamber on the optical bench will not meet PI requirements. Currently each individual PI must design constant-temperature control for the test chamber.

Recommended Action

Since every PI has this need, Facility should investigate providing a constant-temperature control consisting of a closed fluid loop with heat/cold source and both similar to standard commercial baths with digital controllers for near-ambient control (0-30 degrees C, constant temp +/- 0.1 degrees C typical). This could be accessed via quick disconnects on the rack, and controlled via FSAP.

FCF-PDR-017 - No Pulsed Illumination Capability

Statement of Concern

The Facility provides no pulsed illumination capability. Pulsed illumination allows shorter illumination times then achievable with either current electronic shuttering or HFR camera rates. Pulsed illumination also allows PIV capability beyond frame-to-frame particle tracking.

Recommended Action

Provide pulsed illumination. One approach would be to incorporate new driving electronics for existing facility laser diodes and Nd YAg laser.

FCF-PDR-018 - cPCI Bus Card Availability and Fast A/D

Statement of Concern

The Facility has chosen the cPCI bus to accommodate PI needs beyond Facility-provided capabilities. It is not clear that commercially available cPCI cards exist to cover PI needs. The most obvious example is a fast (greater than or equal to 1 Msamples per second A/D) multifunction A/D card. The fastest A/D rate provided by Facility is 125 kS/s.

Recommended Action

Investigate availability of cPCI bus cards and demonstrate that > 1 MS/s A/D is available commercially at competitive costs (compared to PCI cards).

FCF-PDR-019 - Non-Approved Requirement Exceptions

Statement of Concern

The CIR/FIR/SAR design identified a number of requirements that will need exceptions to be granted. Until the exceptions are approved or rejected, the design compliance will remain unresolved and represents an unquantified technical and programmatic risk.

Recommended Action

(1) Include exceptions submittal dates on FCF and rack schedules as appropriate. (2) Finalize and submit all requests for exceptions as soon as possible. (3) Upon exception approval/rejection, modify the requirements and design as necessary.

FCF-PDR-020 - Operations Concept

Statement of Concern

Operations concept of the integrated facility seems missing. Individual racks and experiments were presented but there was no integration of all three in an operations state. How are the ISS resources (power, coolant, downlink, crew time) shared between the facility? Does the timeline support the requirement to complete the required 10 experiments per year? What is the plan for resupply and logistics support? Does the up-mass include PI experiments?

Recommended Action

Develop an integrated operations timeline which demonstrates that the requirements can be met within given resources (power, data stowage, etc.).

FCF-PDR-021 - Power System Constraints on Payloads

Statement of Concern

Power requirements and constraints on FCF core equipment and common equipment need clarification. The power allocated to experiments may be too constrained to achieve the targeted payload support rates. The thermal capabilities and power connectivity should accommodate payload designs which exceed the stated “power available to payloads” in the individual racks.

Recommended Action

Clarify power requirements on all three racks and the available power to payloads for simultaneous operations.

FCF-PDR-022 - Compliance with Utilization Rate Requirements

Statement of Concern

Compliance with requirements for accommodating 5 combustion and 5 fluids experiments per year has not been demonstrated. The Level 1 Requirement includes a utilization rate of 10 fluids and 10 combustion experiments per year, if resources permit. Evidence was not shown that the contractor is incorporating this requirement into the design.

Recommended Action

Perform comprehensive traffic flow analysis of all resources (both flight and ground) for payload integration, testing, on-orbit operations, and ground support.

APPENDIX E - OPEN REQUESTS FOR ACTION (RFAs) FROM PRIOR REVIEWS

CIR-PDR-006 – FCF Stowed Equipment Deployment

Statement of Concern

At the time each FCF rack is deployed to ISS, launch upmass, upvolume, and on-orbit stowage must be provided to allow stowed FCF equipment (i.e., FCF equipment not installed in the racks at launch) to be deployed. It was indicated in the FCF PDR presentations that the equivalent volume of one additional rack may be involved when each FCF rack is deployed to ISS. While the FCF racks themselves are accounted for in ISS manifesting, no specific agreements exist with ISS for FCF logistics to account for the deployment of this stowed equipment.

Recommended Action

Identify specific upmass, upvolume and stowage requirements for stowed equipment to be deployed to ISS with each FCF rack. Verify with ISS that upmass, upvolume and on-orbit stowage requirements are within Utilization Flight allocations. If not, work issues with ISS and reach agreement by CDR.

CIR-PDR-009 – CIR Chamber Cleaning/Contamination Control

Statement of Concern

The cleanliness requirements for the CIR chamber and the windows are sketchy at best. Much more definition of the cleanliness and window performance requirements and plans to achieve and verify are needed.

Recommended Action

A program to define window and chamber internal cleanliness requirements must be initiated. Development of cleaning procedures to meet these requirements must be developed. Laboratory studies must be an integral part of this to verify that following these procedures will meet the defined requirements, including how the cleanliness will be verified on-orbit.